

101568,011

## (12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau(43) International Publication Date  
6 March 2003 (06.03.2003)

PCT

(10) International Publication Number  
**WO 03/018237 A1**(51) International Patent Classification<sup>7</sup>: **B22D 17/30**(21) International Application Number: **PCT/AU02/01141**

(22) International Filing Date: 23 August 2002 (23.08.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
PR 7216 23 August 2001 (23.08.2001) AU  
29303/02 28 March 2002 (28.03.2002) AU

(71) Applicant (for all designated States except US): COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION [AU/AU]; Limestone Avenue, Campbell, Australian Capital Territory 2612 (AU).

(72) Inventors; and

(75) Inventors/Applicants (for US only): MURRAY, Morris, Taylor [AU/AU]; 51 Teal Lane, Briar Hill, Victoria 3088 (AU). COPE, Matthew, Alan [GB/AU]; 118 Jones Road, Somerville, Victoria 3912 (AU).

(74) Agent: PHILLIPS ORMONDE &amp; FITZPATRICK; 367 Collins Street, Melbourne, Victoria 3000 (AU).

(81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

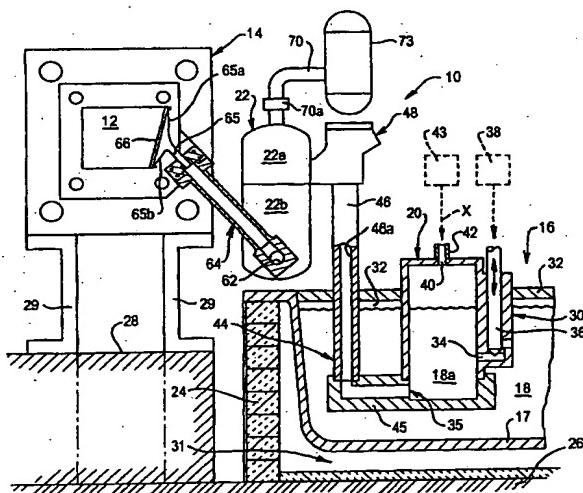
(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

## Published:

— with international search report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: APPARATUS FOR PRESSURE CASTING



WO 03/018237 A1

(57) Abstract: Apparatus for high pressure casting (10) of alloys, includes a molten alloy transfer vessel (22) which has capacity for holding a measured volume of alloy required for transfer to a die tool (14) and sufficient for a single casting cycle to produce at least one casting. The transfer vessel (22) has a valve (48) controlled charging port (51) at an upper region of the transfer vessel (22) by which the measured volume of the alloy is able to be charged into the vessel (22), and an outlet port (62) at or adjacent to a base of the vessel (22), through which the alloy is able to be discharged for flow to a die tool (14). The transfer vessel (22) has a gas supply port (70) at the upper region for the supply of gas above the surface of a measured volume of alloy received therein, whereby the vessel (22) is able to be pressurised for discharging alloy through the outlet port for flow to the die tool (14).

Best Available Copy

## APPARATUS FOR PRESSURE CASTING

This invention relates to apparatus for high pressure casting of light alloys.

The hot chamber process is widely used for high pressure die casting of 5 a range of lower-melting alloys, including those of zinc, lead and tin . In this process, a hydraulic actuator displaces molten alloy from a sleeve, sometimes referred to as a "gooseneck", immersed in molten alloy held in a pot or furnace, to cause the alloy to flow from the sleeve via a nozzle, into a die cavity of a die tool. The hot chamber process is able to minimise exposure of the alloy to 10 turbulence and oxidising gases, while minimising heat loss from the alloy in its flow to the die cavity. However, the process necessitates prolonged contact between components and the molten alloy, and this gives rise to difficulties and precludes application of the process to higher-melting alloys, such as aluminium alloys and magnesium alloys with the exception of the magnesium AZ91D alloy.

15 The cold chamber process also is widely used for high pressure die casting, typically for higher melting alloys such as copper and aluminium. This isolates the hydraulic actuator from the pot or furnace and minimises exposure of components to the molten alloy. However it necessitates metering of alloy to a shot sleeve of the actuator for successive casting cycles, and immediate 20 injection.

In less common processes for low pressure gravity assist casting of aluminium alloy, the molten alloy is caused to flow from a holding furnace to a die cavity by either physical displacement or by air pressure. In the former case, the furnace holding a large volume of the alloy forms a first arm of a U- 25 tube form of flow path, with the die located above a second arm, and the level of alloy is caused to rise in each arm by a large block being immersed in the alloy in the first arm. In the latter case, the furnace is a sealed vessel, and pressurised air supplied to the vessel forces alloy up through a riser pipe into a mould mounted on the upper end of the pipe, above the vessel. A similar air 30 displacement process also has some limited use in casting magnesium alloys, but with the air being mixed with sulphur hexafluoride to minimise oxidation of the alloy in the furnace and with the gas mixture pressurised by a hydraulic actuator.

- The present invention seeks to provide an alternative apparatus for high pressure casting of alloys. Such apparatus of the invention includes a molten alloy transfer vessel which has capacity for holding a measured volume of alloy required for transfer to a die tool and sufficient to produce a given casting, or for 5 simultaneously producing a plurality of given castings which usually are similar.
- 10 The transfer vessel has a valve controlled charging port, at an upper region of the transfer vessel, by which the measured volume of alloy is able to be charged into the vessel; and an outlet port, at or adjacent to a base of the vessel, through which the alloy is able to be discharged for flow to a die tool.
- 15 The transfer vessel also has a gas supply port, at the upper region thereof, for the supply of gas above the surface of a measured volume of alloy received therein whereby the vessel is able to be pressurised for discharging alloy 20 therein through the outlet port for flow to the die tool.

The transfer vessel may be used with a source of pressurised gas from 15 which a supply of the gas is able to be charged to the transfer vessel via the gas supply port. Where this is the case, the transfer vessel preferably is in combination with such source of pressurised gas. The arrangement is such that, with the supply of pressurised gas to the transfer vessel, the measured quantity of alloy is caused to be discharged from the vessel at a flow rate in a 25 required flow rate range, during a single casting cycle.

In an alternative arrangement, the transfer vessel functions as a combustion chamber, with the gas supply port enabling an oxygen-containing gas to be charged to the transfer vessel from gas supply means. In that arrangement, a suitable fuel is able to be charged to the transfer vessel, either 25 via the gas supply port or via a separate fuel supply port, to form a combustible oxygen/fuel mixture. That is, the transfer vessel may be pressurised by igniting that mixture, such as in a manner used for the combustion chambers of an IC engine. Thus, the measured quantity of alloy can be caused to discharge from the transfer vessel, at a flow rate in a required flow rate range, during a single 30 casting cycle by the action of hot combustion gases.

Where the transfer vessel functions as a combustion chamber, it preferably is in combination with means for supplying oxygen-containing gas and fuel, in a metered ratio, and means for igniting the oxygen/fuel mixture. However, the mixture may be ignited spontaneously on coming into the

proximity of the molten alloy in the transfer vessel. Accordingly, it may be convenient either to inject the fuel after the oxygen-containing gas has been charged to the pressure vessel and the gas supply port has been closed. Alternatively, an oxygen/fuel mixture may be charged to or formed in an ante-  
5 chamber which is closed prior to opening the gas-supply port to admit the mixture to the transfer vessel for combustion.

Where the transfer vessel functions as a combustion chamber, the oxygen-containing gas may be oxygen, air or oxygen-enriched air. The fuel may be of any suitable type, such as natural gas, LPG, hydrogen, methanol and  
10 petrol. Where the gas supplied to the transfer vessel is from a pressurised source, and the pressure of the gas, rather than combustion, is to cause the alloy to be discharged from the transfer vessel, the gas may, but need not, contain oxygen, and nitrogen is a suitable alternative.

The transfer vessel is adapted to be pressurised for discharging of alloy therefrom during a casting operation. The vessel therefore needs to be suitable for this. Where, in pressure casting apparatus according to the invention, pressurised gas supply means is in communication with the pressurising port of the transfer vessel, it is operable to supply pressurised gas to the vessel. The supply means is operable to provide a sufficient quantity of the gas at a sufficient high velocity and pressure to cause the alloy to be discharged from the transfer vessel at a flow rate in a required flow rate range. Molten alloy in the vessel is able to be discharged at relatively high flow rate, effectively by an impulse loading. Due to this, the vessel needs to be able to withstand the pressure levels applied, although these may be substantially less severe than  
25 the static pressure levels encountered in conventional pressure die casting. Correspondingly, the locking capacity necessary to keep the die tool closed may be able to be reduced, with overall reduction in the size and capital cost of apparatus for producing castings up to a given maximum weight. Similarly where, in apparatus according to the invention, the transfer vessel functions as  
30 a combustion chamber, the arrangement needs to be able to generate combustion gas pressure sufficient to discharge alloy at a flow rate in a required range. Again, the transfer vessel needs to be able to withstand resultant impulse loading, although this also may be substantially less than those static

pressure levels and locking capacity for the die tool can be able to be reduced with similar benefit.

The flow rate for alloy being discharged from the transfer vessel most preferably is high relative to flow rates achieved by mechanical or pneumatic metal displacement arrangements used in the known casting processes discussed above. Required flow rates can vary with the base metal of the alloy being cast. However, in each case, the flow rate most preferably is such as to achieve a relatively high runner flow rate for the alloy and, hence, a relatively short die cavity fill time.

The supply of pressurised gas or the generation of combustion gases, by which the transfer vessel is pressurised for discharging alloy from the vessel to a die tool, is the principal determinant of alloy flow rate during a casting cycle for a given arrangement of transfer vessel, die tool and alloy flow path from the transfer vessel to the or each die cavity of the die tool. That is, for such given arrangement, it is the pressure and flow rate of gas from the supply to the transfer vessel or the pressure of combustion gases which determines the alloy flow rate. However, from one arrangement to another, there is a number of variables which, for a given pressure and flow rate of the gas from the supply, or the pressure of combustion gases determines the alloy flow rate. These include the volume and configuration of the transfer vessel, the measured quantity of alloy, the flow characteristics of the alloy, and the length and cross-section of the flow path for the alloy. However, notwithstanding these variables, it is preferred that the gas pressure and flow rate from the supply, or combustion gas pressures, are such that, as indicated above, the alloy flow rate is relatively high.

The required relatively high alloy flow rate is to achieve a high alloy flow velocity in a runner, or a respective runner, for the, or each, die cavity of the die tool. However, the relatively high alloy flow rate most preferably is achieved in the alloy flow path, over a short flow path length adjacent to, at or just beyond, the opening to the die cavity, with that short flow path length increasing in cross-sectional area from the runner cross-sectional area. That is, rather than the or each runner ending at a conventional constriction or gate, there preferably is an expansion region or port (herein referred to as a "CEP"), through which alloy from the, or each, runner flows to the or each die cavity. The pressure and flow

rate of gas supplied to, or the combustion gas pressure generated in, the transfer vessel according to the present invention preferably is such as to achieve an alloy flow velocity through an inlet end of the CEP in excess of about 40 m/s, preferably in excess of about 50 m/s, such as from 140 m/s to 165 m/s,  
5 for a magnesium alloy and in excess of about 60 m/s, such as from 80 m/s to 120 m/s, for preferably from 80 to 110 m/s, aluminium alloys. For other alloys, the CEP inlet flow velocity may be similar to that for aluminium alloys, although the range can vary with the unique characteristics of individual alloys. The increasing cross-sectional area of a CEP is such that, for each alloy, the flow  
10 velocity at the outlet end of the CEP is from 50 to 80%, such as from 65 to 75%, of the flow velocity at the CEP inlet end. With use of the CEP under these conditions, the state of the molten alloy in its flow through the CEP is changed to a semi-solid state possessing thixotropic properties and that state is able to be maintained into the or each die cavity..

15 The pressure and flow rate for gas charged to, or the combustion gas pressure generated in, the transfer vessel can be considered from another perspective. The gas pressure and flow rate or combustion generated pressure preferably is such that sprue metal separated from a die tool with a casting exhibits a required microstructure. The gas pressure and flow rate or generated  
20 pressure may be such that the microstructure of sprue metal is characterised by fine banding normal to the alloy flow direction and having, for example, a spacing (or wavelength) between centres of successive bands which is of the order of about 40 µm for a magnesium alloy and about 200 µm for aluminium and other alloys. This banding, attributed to dynamic fluid effects, is found to  
25 result from segregation of alloy elements which differ sufficiently in density. Thus, for example, with a magnesium alloy having aluminium as a principal alloy element, such as AZ91D, it is found that successive bands high in aluminium and high in magnesium are able to be formed, with the high magnesium band containing fine, rounded or spheroidal, or degenerate dendrite, primary particles and the high aluminium bands having an excess of intermetallic particles, such as Mg<sub>17</sub>Al<sub>12</sub> particles. Similarly, with an aluminium  
30 alloy having magnesium as a principal alloy element, aluminium-rich and magnesium-rich bands are able to form but, in this case, it is the aluminium-rich

bands which contain fine, rounded or spheroidal, or degenerate dendrite primary particles.

With each basis for assessing suitable pressure and flow rate for gas charged to the transfer vessel, or the pressure of generated combustion gas, it 5 is found that sound castings, substantially free of porosity and having a desirable fine microstructure are able to be produced. In each case, it appears that despite the alloy being in a substantially fully molten state in the transfer vessel, prior to the inflow or generation of pressurising gas, the relatively high metal flow rate results in a large degree of undercooling and a rapid growth rate 10 of fine primary particles, and/or generation of high pressure pulses along the flow path (in particular in the CEP), which result in the segregation banding.

While achieving such alloy flow rates, and high alloy flow velocities through a CEP, particularly for producing larger castings, the pressure prevailing in the transfer vessel can be high. However, despite this, the transfer 15 vessel readily is able to be manufactured to safely accommodate such pressures since the volume of the vessel is relatively small, in some instances with a capacity of 0.5 litres or less, in needing to contain only sufficient alloy for a single casting operation. For this, it is desirable that the vessel be of a suitable material, configuration and wall thickness to be able to contain 20 substantially in excess of the applied gas pressure to ensure safe operation.

Pressure casting machine according to the invention includes apparatus according to the invention having a transfer vessel, and further includes means for supplying molten alloy to the transfer vessel. The invention enables a number of different arrangements for the relationship between the alloy supply 25 means and the transfer vessel.

The pressure casting machine according to the invention most preferably includes a pot or furnace in which a supply of the alloy for successive casting operations is kept molten at a suitable temperature for casting. In such case, the supply means may be operable to pass a measured quantity of alloy, from 30 the supply in the pot or furnace, into the transfer vessel. For this purpose, the supply means is associated with the pot or furnace and may be at least partly submerged in the supply of alloy in the pot or furnace.

In a first arrangement, the supply means may comprise a plunger which is vertically movable in a cylindrical housing mounted in the pot or furnace, with

the plunger movable in the housing between a raised position in which it clears an opening in the cylindrical wall of the housing for drawing alloy into the housing, and a depressed position in which it displaces the alloy from the housing into the transfer vessel.

5 In a second arrangement, the supply means again is mounted in a pot or furnace containing the molten alloy. The supply means of the second arrangement includes a housing which is mounted in the pot or furnace but which, rather than having a plunger movable therein, is closed at its upper end and is provided with an inlet port by which a pressurised gas is able to be  
10 supplied to displace alloy from the supply means into the transfer vessel.

With either arrangement for the supply means, the transfer vessel in one form may define a sleeve which is closed at an upper end by a plunger, with the plunger of the transfer vessel being movable between an upper position in which it clears an opening in the wall of its sleeve defining the charging port and  
15 a lower position in which the plunger functions as a valve closing the charging port. In such arrangement, the plunger of the transfer vessel may have an axial bore therethrough which defines the gas supply port by which, with the charging port closed by the plunger, pressurised gas is able to be supplied to the transfer vessel for discharging alloy from the vessel through the outlet port. In an  
20 alternative form, the transfer vessel may comprise a housing which, apart from the charging, outlet and gas supply ports, is sealed.

The transfer vessel may be mounted in the pot or furnace, such as adjacent to the supply means. Where this is the case, the apparatus has the benefit of a conventional hot chamber die casting machine in that molten alloy temperature, prior to a casting operation, is able to be controlled by the pot or furnace temperature. Thus, relatively close temperature control is possible. As with the conventional hot chamber machine, there is prolonged contact between components and the molten alloy. However the arrangement of the invention obviates the need for the relatively complex, high cost form of sleeve or  
25 gooseneck necessary in conventional hot chamber die casting machine. That is, the housing for the supply means can be of simple, readily machinable form. Also, flow of alloy from that housing to the transfer vessel can be by conduit means of any suitable form, as the conduit means is required simply to enable  
30 flow of alloy from the supply means to the transfer vessel and does not need to

communicate with or define a nozzle for engaging with the die tool. As a consequence, the supply means and the conduit means are more amenable to manufacture in a form necessitating only simple machining and hence they are able to be manufactured of a ceramic or other non-ferrous material which is better suited to prolonged immersion in molten alloy than a gooseneck made of a ferrous alloy. The apparatus of the invention therefore can better facilitate casting of higher-melting alloys, such as copper and aluminium alloys.

Communication between the supply means and the transfer vessel can be by conduit means extending therebetween. In a first form, the conduit means is continuous between an outlet port of the supply means housing and the charging port of the transfer vessel. In that first form, the conduit means may have a first portion which extends upwardly in the wall of the supply means housing and which, at its lower end, is in communication with the interior of the housing, and a second portion which extends laterally from the upper end of the first portion to the charging port of the transfer vessel. A control valve for the charging port, for enabling and preventing communication between the supply means and the transfer vessel, as required, most conveniently is associated with the second portion of the conduit means.

In the first form of the conduit means, the control valve may have a valve head which is mounted on a valve stem for movement across the second portion of the conduit means, or for movement longitudinally with respect to the second portion. In the former case, a valve seat against which the valve head is sealable may be defined within the conduit means, such as at the upper end of the first portion, with the valve stem extending from the valve head away from the first portion. In the latter case, a valve seat against which the valve head is sealable may be defined by the second portion of the conduit means, such as at or adjacent to the charging port, with the valve stem extending from the valve head, within the second portion, away from the charging port. In each case, the valve stem projects exteriorly of the conduit means to an actuator operable to close and open the valve, as required. In each case, the second portion of the conduit means preferably is inclined downwardly towards the charging port to enable drainage of alloy therefrom into the transfer vessel, to thereby minimise risk of alloy at the valve seat impeding closing of the valve.

In a second form the conduit means terminates short of the charging port. In that second form, the conduit means preferably has first and second portions which extend similarly to those described for the first form. However, in the second form, the end of the second portion remote from the first portion 5 terminates above an open-topped receptacle on the exterior of the transfer vessel, adjacent to the charging port. The conduit means thus is able to discharge alloy into the receptacle for flow into the transfer vessel, via the charging port. The receptacle may extend to one side of the transfer vessel or it may be of annular form and extend around the transfer vessel. In the case of 10 an annular receptacle, the charging port may be one of a circumferential array of such ports around the transfer vessel.

With the second form of the conduit means, for discharging alloy into a receptacle on the transfer vessel, the transfer vessel may be of the above-described form in which it defines a sleeve closed at its upper end by a plunger. 15 Thus the plunger, when in its upper position, enables alloy to flow into the vessel from the receptacle, via the or each charging port. When the plunger is in its lower position, it closes the or each charging port.

With that second form of the conduit means, the plunger in its lower position is able to seal the transfer vessel against pressurising gas blowing from 20 the vessel through the or each charging port. However, in the event that the valve comprising the plunger is prevented from fully sealing the transfer vessel, such as due to its movement being blocked or the valve malfunctioning, the gas is able to vent from the receptacle. As a result, undesirable blowing of gas into the supply means is precluded, due to the conduit means terminating short of 25 the charging port.

With the first form of the conduit means, a vent preferably is provided at the valve so that, again, blowing of gas into the supply means is prevented in the event that closing of the valve is prevented by a blockage or malfunctioning 30 of the valve. The vent may be provided by a further conduit portion which extends upwardly from the second portion adjacent to the vessel. Such further portion is able to provide a path of low resistance to the passage of the gas therethrough in preference to flow through the first conduit portion against the pressure head of alloy in the supply means. If necessary, the further conduit portion may have a relief valve therein which opens in response to gas

pressure, but not in response to a lower pressure at which alloy is caused to flow from the supply means to the transfer vessel.

It also is necessary that there not be any back-flow of molten alloy from the transfer vessel to the supply means, although a number of factors assist in ensuring this. A first factor involves operation of the supply means to provide only sufficient alloy to the transfer vessel for a single casting operation, with this resulting in a maximum level of alloy in the transfer vessel which is below the upper level of the vessel and, hence, below the charging port. A second factor is location of the gas supply port in the upper region, where that port is used for the supply of pressurised gas from a source of supply, so that gas pressure is applied to the upper surface of the alloy. However back-flow of alloy also is ensured by valve control of the charging port since, with this port closed after the supply of a measured volume of alloy to the transfer vessel, the upper region of the vessel is sealed other than to enable the inflow of pressurising gas. However, at least in preferred arrangements, a vent is provided at the charging port whereby, in the event that full closing of the charging port valve is prevented by a blockage or malfunctioning of the valve, pressurising gas is able to be vented from the apparatus. Such venting not only prevents back-flow of the gas to the molten alloy supply means, but also prevents any displacement of alloy in the transfer metal in a manner enabling flow-back of the alloy to the supply means.

Particularly where, as described above, the gas supply port is defined by a plunger in the upper end of the transfer vessel, the pressurising gas preferably is prevented from issuing as a jet which impinges narrowly on the upper surface of alloy in that vessel. For this purpose, gas flow control means is provided at the pressurising port to prevent such jet. The flow control means may be in the form of a helical baffle which guides the gas into a helical flow path towards the alloy. Alternatively, the flow control means may be in the form of a conical member which diffuses the gas flow into a conical stream. Such flow control also can be provided in other arrangements in which the pressurising port opens directly towards the upper surface of the alloy.

The pressurising port need not open directly towards the upper surface of the alloy in the transfer vessel. This is possible even where that port is defined by a plunger. Particularly where the gas supply port is defined by a wall

of the transfer vessel, the port preferably opens laterally such that a gas jet issuing therefrom does not impinge directly on the upper surface of the alloy. In each arrangement, the gas supply port may be directed so that a jet issuing from it is constrained by the inner surface of the transfer vessel to follow a 5 helical path in that vessel by which it is directed obliquely towards the alloy upper surface. Thus where, for example, the gas supply port is defined by a wall of the transfer vessel, the port may open so as to direct the pressurising gas somewhat tangentially with respect to the inner surface of that wall, but preferably also with a downward component towards the upper surface of alloy 10 in the transfer vessel.

As indicated above, the transfer vessel may be mounted in the pot or furnace, such as adjacent to the supply means. However, in an alternative arrangement, the transfer vessel may be mounted outside the pot or furnace. The transfer vessel may be laterally adjacent, or either above or below, the pot 15 or furnace. Where the transfer means is outside the pot or furnace, it is not able to be maintained at a substantially constant temperature level by being immersed in molten alloy. It therefore may be necessary for alternative heating means to be provided, to maintain alloy in the transfer vessel at a required temperature for casting. The heating means may provide flame, induction or 20 other convenient form of heating. Additionally, or alternatively, the alloy temperature may be controlled by use of a heated nozzle through which the alloy passes between the transfer vessel and the die cavity.

Where the transfer vessel is outside the pot or furnace, there again needs to be conduit means by which alloy is caused to flow from the supply 25 means to the transfer vessel. The conduit means may be of a form described above for arrangements in which the transfer vessel is in the pot or furnace, although other forms can be used. In particular, a conduit from the supply means may pass through a side wall or base of the pot or furnace to the transfer vessel. Alternatively, for some alloys, it is desirable that the pot or 30 furnace be provided with a cover, to protect the alloy from oxidation, and the conduit can pass through such cover.

The pressure casting machine according to the invention provides a number of practical benefits, while it also is well suited to modification to suit the needs of a particular application. Compared with conventional machines used

for hot and cold chamber processes, the apparatus is relatively low in capital cost, compact and simple to operate. It is well suited to automated operation, once set up for production of a given casting. Also, it is relatively simple to change from production of one form of casting to another.

- 5       A further practical benefit of the invention which is of considerable importance, is that it very substantially reduces the loading on the die tool components at the end of a casting cycle. With a hot-chamber die casting machine, alloy displacement through the gooseneck is by means of a hydraulic actuator which has a piston by which the alloy is forced through the goose neck.
- 10      The kinetic energy of the actuator/piston arrangement has to be absorbed once the die cavity is filled, with this being transmitted through the molten alloy to the die tool components. The instantaneous load on those components can be up to 3.5 times the machine pressure. Even in a cold-chamber machine, the impulse loading on the die components can be very substantial, due to the
- 15      kinetic energy of the shot-sleeve piston and its actuating mechanism needing to be absorbed on completion of filling of the die cavity. In contrast, the pressurising gas, or the combustion gases, used to achieve die cavity filling with apparatus according to the present invention, has negligible effective mass, and substantially no impulse loading on die tool components on completion of filling
- 20      of the die cavity. Despite this, complete filling of the die cavity under high pressure is achieved.

- A practical benefit of the very low impulse loading of die tool components is that the risk of die tool failure is minimised. However, a further important benefit is that larger castings can be made on a given machine, or that smaller machines can be used to produce a given casting, in terms of die tool component wall thicknesses and die tool clamping mechanisms.

- The pressure casting machine of the invention is suitable for production of castings using a single cavity die tool or a multi-cavity die tool. Moreover, given the need for only low pressure in the supply means housing, and the 25     relatively small capacity of the higher pressure transfer vessel, the machine is well suited to that housing and vessel being made of a material able to withstand prolonged contact with higher melting point alloys such as copper and aluminium. Thus, the machine obviates a limitation of the hot chamber process, and also the need for the shot sleeve metering of the cold chamber process.

The machine of the invention facilitates a variety of arrangements for mounting a die tool relative to the transfer vessel. Thus, the die tool can be above, below or to one side of the transfer vessel. Also the machine of the invention is amenable to being scaled up, to enable concurrent or sequential casting in two or more die tools. Thus, a common supply means can be operable to concurrently or sequentially supply a measured quantity of alloy to each of a plurality of transfer vessels, with each transfer vessel being operable to provide a flow of alloy to the or each die cavity of a respective die tool. In such multi-transfer vessel system, the transfer vessels can be arranged around the common supply means, such as in a horizontally spaced array or any other convenient array. Moreover, particularly where the supply means is operable to sequentially supply alloy to successive transfer vessels, the measured quantity of alloy supplied to each can be the same or different, with each transfer vessel having the same or a different capacity and operable to provide a flow of alloy to respective die tools for producing the same form of casting or different forms of castings. A common source or a respective source of high pressure gas can be used for each transfer vessel.

In order that the invention may more readily be understood, reference now is directed to the accompanying drawings, in which:

20 Figure 1 is a partial sectional view through light alloy casting apparatus according to a first embodiment of the invention;

Figure 2 is a partial sectional view of the transfer vessel according to an embodiment of the invention, of the apparatus of Figure 1;

25 Figure 3 shows partial detail of an alternative embodiment of a transfer vessel according to the invention;

Figure 4 shows the lower portion of a transfer vessel in section, illustrating an alternative coupling to a die mould;

30 Figure 5 is similar to Figure 4, but illustrates a further alternative coupling;

Figure 6 is a side elevation of the transfer vessel of Figure 5;

Figure 7 is a partial sectional view through light alloy casting apparatus according to another embodiment of the invention;

Figure 8 is similar to Figure 7, but illustrates casting apparatus according to a still further embodiment of the invention; and

Figure 9 illustrates a still further embodiment of the invention.

In Figure 1, there is shown pressure casting apparatus 10, for use in casting an article in the die cavity 12 of die tool partly shown at 14. The apparatus 10 includes a furnace 16 having a pot 17 containing a quantity of 5 molten light alloy 18, supply means 20 and a transfer vessel 22 mounted (by means not shown) above the furnace 16.

The furnace 16 includes refractory support 24 by which pot 17 is mounted on a base structure 26. Adjacent to furnace 16, structure 26 has a raised part 28 on which die tool 14 is supported on a stand 29.

10 The temperature of molten alloy 18 in furnace 16 is maintained by any suitable heating means (not shown). For example, required heat energy input may be provided by a flame heating from within the space 31 below pot 17.

15 The supply means 20 includes a housing 30 which is partly immersed in the alloy 18 in pot 17. An upper portion of housing 30 projects through a cover 32 of furnace 16. Cover 32 supports housing 30 and enables a protective atmosphere to be maintained in space 32 above alloy 18 for minimising oxidation of the alloy.

Housing 30 has an inlet port 34 in its peripheral wall, below the level of 20 alloy 18 in pot 17. A control valve 36, which is operably mechanically, hydraulically or pneumatically by actuator 38 on top of housing 30, enables port 34 to be opened for flow of alloy 18a into housing 30 and to be closed during discharge of alloy 18a from housing 30. In the top of housing 30, above cover 32, there is an inlet port 40 having a connector 42 for coupling housing 30 to a source 43 of low pressure gas, as represented by arrow X. Also, extending 25 from the base of housing 30 to transfer vessel 22, there is conduit means 44 comprising lateral conduit 45 and riser conduit 46. The arrangement is such that, with inlet port 34 closed by valve 36, a measured quantity of alloy 18a in housing 30 is able to be forced from housing 30, into transfer vessel 22 by flow 30 through an outlet port 35 of housing 30 and then through conduit means 44, by low pressure gas charged into housing 30 via connector 42 and inlet port 40.

The transfer vessel 22 has an upper portion 22a on which a valve unit 48 is mounted. As shown in Figure 2, the upper end of riser conduit 46 communicates with vessel 22 through valve unit 48. An upwardly extending bore 49 defined by unit 48 provides a continuation of the bore 46a of conduit 46.

Unit 48 also defines a bore 50 which intersects bore 49 and is inclined downwardly to communicate with the interior of vessel 22 through an alloy charging port 51. The arrangement is such that alloy 18a forced from housing 30 into transfer vessel 22 flows from bore 46a of conduit 46, into bore 49 and 5 from bore 49, it flows into vessel 22 via bore 50.

At the charging port 51 of vessel 22, bore 50 is enlarged to define a valve seat 52. A valve 54 is provided in, and is adjustable longitudinally of, bore 50, with valve 54 having a valve head 54a co-operable with valve seat 52 to close bore 50 and a valve stem 54b which extends along bore 50 to the exterior of 10 valve unit 48. The outer end of bore 50 is stepped to accommodate a gland 55 which provides a seal around valve stem 54b, while a nut 57 is threaded in the outer end of bore 50 to retain gland 55. An actuator 56 located exteriorly of unit 48 is operable to provide longitudinal movement of valve 54, as represented by arrow Y, for enabling or preventing flow of alloy 18a into vessel 15 22 via bore 50 and port 51.

A continuation of bore 49, above bore 50, opens exteriorly of unit 48. However, a valve 58 is provided in an enlargement 49a of bore 49 so that the continuation of bore 49 normally is closed, with valve 58 providing a safety vent. As shown, the valve 58 includes a valve seat 58a defined by the enlargement 20 49a of bore 49 and a ball 58b which provides a seal with seat 58a. Under a sufficient gas pressure in bores 49 and 50, valve 58 is able to open by ball 58b being lifted off seat 58a, to enable the gas pressure to be dissipated by gas venting through the open, upper end of bore 49. To enable this venting, enlargement 49a of bore 49 is provided with ribs 60, such that the gas is able to 25 pass around ball 58b, through spacings between ribs 60, and through the upper end of bore 49.

Alloy is able to flow into transfer vessel 22 to provide a measured quantity of alloy 18b therein, to a level below the inner end of bore 50. In Figure 2, the alloy is shown as being contained in the lower portion 22b of vessel 22. With reference to Figure 1, the alloy 18b is able to be discharged from vessel 30 22, via an outlet port 62 at or adjacent to the base of portion 22b of vessel 22. The alloy 18b is caused to flow from port 62, via a conduit 64, to die cavity 12 of tool 14. From conduit 64, the alloy flow in tool 14 is via a main runner 65, then along each of oppositely extending tapered tangential runners 65a and 65b, and

then into die cavity 12 via a narrow gate 66 extending along runners 65a and 65b.

To enable alloy 18b to be discharged from transfer vessel 22 to die cavity 12, upper portion 22a of vessel 22 is provided with a pressurising port 68, shown in Figure 2. Port 68 is defined by a connector 69 to which is coupled a supply line 70 from a source of high pressure gas 73. Thus, on opening a valve 70a in line 70, pressurised gas is able to be charged into vessel 22 and, with valve 54 closed, to pressurise vessel 22 to a level causing alloy 18b to be discharged. Preferably connector 69 is directed tangentially with respect to the circular internal surface of vessel 22, whereby the gas entering via port 68 is not caused to impinge directly on the upper surface of alloy 18b. On completion of discharge of alloy 18b from vessel 22, valve 70a is closed.

With use of the apparatus 10 of Figures 1 and 2, valve 36 of housing 30 and valve 54 of unit 48 initially are open. Alloy 18 in pot 17 then is able to flow under gravity into housing 30, via inlet port 34. Thus a required quantity of alloy 18a is established in housing 30, with this rising to a common level with alloy 18 in pot 17. The alloy 18a fills the bore 45a of conduit 45 and rises in bore 46a of conduit 46 to that common level.

After establishing the required quantity of alloy 18a in housing 30, valve 36 is closed, and low pressure gas is charged to housing 30, via inlet port 40, from the source 43 of low pressure gas coupled to connector 42. The level of alloy 18a in housing 30 is slowly depressed by the low gas pressure, causing alloy 18a to flow through conduit means 44 to provide a measured quantity of alloy 18b in transfer vessel 22. The measured quantity of alloy provided in vessel 22 is sufficient to fill die cavity 12 (or each die cavity, if there is more than one). That is, the quantity is sufficient for a single casting cycle for the die tool (represented only by one tool part 14).

On establishing the measured quantity of alloy 18b in transfer vessel 22, valve 54 is closed. Valve 70a then is opened to enable high pressure gas to be charged into vessel 22 at a sufficient pressure and flow rate, via pressurising port 68, from the source 73 of high pressure gas coupled to connector 69 by supply line 70. The level of alloy 18b in vessel 22 is rapidly depressed by the high pressure gas charged into vessel 22. This causes alloy 18b to flow at a high rate through outlet port 62, conduit 64, runners 65, 65a and 65b, to rapidly

fill die cavity 12 of tool 14 through gate 66. Valve 54 is kept closed, while valve 70a is kept open, until solidification of alloy in cavity 12 progresses back to a required solid/liquid interface in runner 65. After this, valve 70a is closed and valve 54 is opened, to enable molten alloy in runner 65 and conduit 64 is able to flow back into transfer vessel 22. The die tool 14 then is able to be opened to enable ejection of an article cast in die cavity 12.

The source 73 can be of any suitable form for charging pressurised gas to vessel 22 at a sufficient pressure and flow rate. The gas pressure and flow rate is to be such as to achieve a rate of discharge of alloy from vessel 22 such that alloy flow into die cavity 22 is at a suitable rate for the particular alloy, as detailed later herein, or such that sprue metal separated with the (or each) casting produced has a required microstructure, as also detailed later herein.

The need for solidification back to a suitably located solid/liquid interface, and the flow back of alloy to vessel 22 necessitates that, in addition to the measured quantity of alloy charged to vessel 22 for each casting cycle, there is a further quantity of alloy in vessel 22. That further quantity is sufficient to ensure that, on completion of filling die cavity 12, runners 65, 65a and 65b are filled with alloy. Also where, as shown, conduit 64 extends upwardly and port 62 opens laterally, the further alloy needs to be sufficient to fill conduit 62 while still at least covering port 62. However, once initially established, that further quantity is retained after each casting cycle.

To enable alloy to flow back into vessel 22 after solidification of a casting, valve 54 may be opened, to enable pressurising gas to vent through valve 58. However, particularly where the high pressure gas contains a constituent such as sulphur hexafluoride, it can be preferable to recycle the gas rather than simply allow it to vent to atmosphere. Also, the gas will be at an elevated temperature and, regardless of its composition, it may be preferable that it not be simply vented after each casting cycle. In each case, valve 58 may be provided simply as a safety measure in case closing of valve 54 is prevented. The vessel 22 therefore may be provided in upper portion 22a with a further valve (not shown) at pressure release port 72. The valve at port 72 may, when opened, provide communication between vessel 22 and a line by which gas is able to be exhausted from vessel 22 for recycling to the high pressure gas source 73.

The arrangement of Figure 3 generally will be understood from the description of Figure 2 and, for ease of description, the same reference numerals plus 100 are used for corresponding parts. The principle difference is the provision of valve 158 in a sub-assembly 74 mounted on top of unit 148 and providing an extended continuation of bore 149. Thus venting gases are able to be discharged at a higher level, away from the transfer vessel (not shown). While the increased height, as depicted in Figure 3, is relatively small, it will be appreciated that this can be increased as required by increasing the length of the lower portion of sub-assembly 74 shown as engaged by threaded coupling 74a between sub-assembly 74 and unit 148.

Figure 4 shows an alternative arrangement for the lower portion of a transfer housing for apparatus 10 of Figure 1. In Figure 4, corresponding parts have the same reference numeral, plus 200. The lower portion 222b of vessel 222 of Figure 4 differs from that shown in Figures 1 and 2 in the form of the conduit 264 and its connection to die tool 214. As shown, conduit 264 is defined partly within the wall of lower portion 222b of transfer vessel 222, and partly by a pipe 76 formed integrally with and projecting laterally from lower portion 222b. The bore 76a of pipe 76 is tapered at an enlarged outer part thereof, and sealingly receives a tapered end 78 of a nozzle 79 which defines a bore 79a providing a continuation of conduit 264. The other end 80 of nozzle 79 is tapered and sealingly fits in a tapered seat 214a of die tool 214, to enable direct injection of alloy received from transfer vessel 222 into the sprue region 214b of tool 214 leading to the die cavity (not shown).

Figures 5 and 6 show a further alternative form for the lower portion of a transfer vessel. This has some characteristics in common with the respective arrangements of Figure 1 and the alternative arrangement of Figure 4. In Figures 5 and 6, parts corresponding to those of Figure 1 have the same reference numeral, plus 300.

The conduit 364 leading from the lower portion 322b includes a pipe 81 which is formed integrally with portion 322b of the transfer vessel 322 and projects laterally outwardly from outlet port 362. Conduit 364 is in the form of an L-shaped pipe, one arm 364a of which is tapered to sealing fit in the tapered bore 81a of pipe 81, and the other arm 364b of which extends upwardly from pipe 81. As indicated by arrows "A" in Figure 5, a clamping force can be

provided by means operable from opposite sides of vessel 322 to forcefully retain arm 364a in bore 80a. However, as indicated by arrows "B" in Figure 6, arm 364a can be rotated on the axis of arm 364a, prior to the application of a clamping force, to adjust the orientation of arm 364b as required, relative to  
5 vessel 322.

In large part, the arrangement of Figure 7 will be understood from the description of apparatus 10 of Figure 1. In Figure 7, parts corresponding to those of apparatus 10 of Figure 1 have the same reference numeral, plus 400.

In apparatus 410 of Figure 7, supply means 420 and transfer vessel 422 again are immersed in alloy 418 contained in a pot 417 of a furnace (not shown). In this instance, supply means 420 includes an open-topped, cylindrical housing 430 in which a piston 84 is reciprocal. The rod 84a of piston 84 projects through a bearing 85 in the cover 432 of pot 417, and is connected to an actuator (not shown) by which piston 84 is able to be raised and lowered in housing 430. With piston 84 in its uppermost position, as illustrated, it clears inlet port 434 of housing 430, enabling alloy to flow into and fill housing 430. As piston 84 is forced down to its lowermost position, shown by dotted-line 84b, it first closes port 434 and then forces a measured quantity of alloy from housing 430, via outlet port 435 of housing 430 and conduit means 444.

20 In the arrangement of apparatus 410, the main part of conduit means 444 is defined within a thickened wall section of housing 430. At the upper end of housing 430, conduit means 444 includes a discharge portion 444a.

From conduit means 444, alloy discharges into an open-topped, funnel-like receptacle 86 mounted on one side of transfer vessel 422. The receptacle 86 has an open-topped bowl portion 86a into which alloy, forced through conduit means 444 from vessel 430 by piston 84, is able to flow. At the base of bowl portion 86a, receptacle 86 has a conduit portion 86b by which alloy in bowl portion 86a is able to flow under gravity so as to enter transfer vessel 422 via charging port 451.

30 Vessel 422 is of cylindrical form. It has an upper portion defined by a sleeve 87 on which receptacle 86 is mounted, and a lower portion 88 defined by a bore formed in an enlargement 417a of pot 417. The lower end of sleeve 87 is tapered, so as to be a neat fit in a frusto-conical seat 89 defined at the upper end of lower portion 88. The vessel 422 has an outlet 462 at the base of lower

portion 88, from which alloy is able to be displaced via a conduit 464. The form and arrangement of conduit 464 may be similar to conduit 64 of Figure 1, and provides for the flow of alloy from vessel 422 to a die tool (not shown). However, whereas the angle at which conduit 64 of Figure 1 extends may be 5 able to be varied (as with conduit 364 of Figure 5 and 6), conduit 464 extends at a fixed angle. Despite this, the arrangement may be such that conduit 464 extends horizontally as shown or, by suitable angling of outlet port 462, at any other convenient angle (such as depicted in the broken outline).

The top of sleeve 87, comprising the upper portion of transfer housing 10 422, is closed by a piston 90 which is able to be reciprocated by a rod 91 which passes through cover 432 of pot 417 to an actuator (not shown). In its raised position shown, piston 90 clears charging port 451, and thereby enables alloy in receptacle 86 to flow into transfer vessel 422. However, in a lower position, piston 90 extends across and provides a seal at port 451.

15 Piston 90 defines a pressurising port 468 for transfer vessel 422. Via port 468, high pressure gas is able to be charged into vessel 422 from a supply source 473 from which the gas flows along bore 92 defined through rod 91 and piston 90. Thus, with port 451 closed by piston 90 after a measured quantity of 20 alloy has been received into transfer vessel 422 from supply means 420, the alloy is able to be forced from vessel 422 for flow through conduit 464, by charging pressurised air into vessel 422 through port 468.

Overall operation with apparatus 410 readily will be understood from description provided in relation to Figure 1. However, as with gas supply source 25 73 of apparatus 10 of Figure 1, source 473 is operable to supply gas to vessel 422 at a pressure and a flow rate sufficient, for the alloy used, to achieve alloy discharge from vessel 422 as detailed herein with reference to filling die cavity 12 of apparatus 10 and/or to achieving sprue metal microstructure for a casting produced with apparatus 10.

Figure 8 schematically illustrates a further arrangement. Again, the 30 arrangement of Figure 8 will in large part be understood from the description of Figures 1 and 7. In Figure 8, parts corresponding to those of apparatus 410 of Figure 7 have the same reference numeral, plus 100.

In apparatus 510 of Figure 8, supply means 520 and transfer vessel 522 again are immersed in alloy 518, although the pot and furnace containing the

alloy have been omitted. As in Figure 7, supply means 520 is in the form of a cylindrical housing 530 from which alloy received therein, via port 534, is able to be displaced by piston 184, by means of an actuator (not shown) acting to lower rod 184a of piston 184. The arrangement is operable to displace a measured 5 quantity of alloy from housing 530 of supply means 520 to transfer vessel 522, by flow through outlet port 535, and portions 544a and 544b of conduit means 544.

The portion 544a of conduit means 544 is defined by a thickened wall portion of housing 530, and extends upwardly from port 535. The portion 544b 10 of means 544 extends outwardly and downwardly from adjacent the top of housing 530 to the charging port 551 of transfer vessel 522. At the junction of portions 544a and 544b, a valve in the form of a piston 92 is mounted in the thickened wall portion of housing 530. An actuator (not shown) is connected to a rod 93 of piston 92, to enable the latter to be raised or lowered, to open or 15 close conduit means 544, for enabling or preventing flow of alloy from supply means 520 to transfer vessel 522.

Vessel 522 is functionally similar overall to vessel 22 of Figure 1, in that it has a pressurising port 568, by which high pressure gas is able to be charged 20 into vessel 522 to force alloy in vessel 522 to discharge via outlet 562 and conduit 564. The gas is supplied through port 568 via a pipe 94, from a supply source 573. Thus, with piston 92 lowered to close conduit means 544, vessel 522 is able to be pressurised to cause that flow.

The measured quantity of alloy received into vessel 522 from supply means 520 may, for example, be such as to raise the level of alloy in vessel 522 25 from a base level "A" to a filled level "B" below charging port 551. The quantity of alloy between those levels is sufficient for a single casting cycle. With vessel 522 pressurised, the alloy level typically will be depressed slightly below level "A". However, with some flow of alloy back into vessel 522 on completion of a casting cycle and release of gas pressure in vessel 522, the level of alloy in 30 vessel 522 returns to level "A" in readiness for a further measured quantity of alloy being received from supply means 520.

The conduit 564, has a portion 564a which extends outwardly from outlet 562, and a portion 564b which extends upwardly from the outer end of portion 564a. A nozzle 95, which is a continuation of portion 564b, provides

communication between conduit 564 and a die tool (not shown) mounted directly above apparatus 510. A heating coil 96 can be provided around nozzle 95 to enable maintenance of the temperature of alloy flowing therethrough. Also, if required, similar coils 96a, 96b and 96c can be provided around the 5 upper extent of transfer vessel 522, portion 544b of conduit means 544 and the upper extent of housing 530 of supply means 520, respectively. Thus, the temperature of alloy is able to be controlled to an extent greater than is provided by the temperature of the body of alloy in which supply means 520 and transfer vessel 522 are immersed, such that the temperature of alloy entering the die 10 tool can be monitored and controlled.

Again, overall operation with apparatus 510 of Figure 8 will be understood from description of preceding embodiments, including apparatus 10 of Figure 1 and apparatus 410 of Figure 7. Again, as with gas supply source 73 of apparatus 10 of Figure 1, source 573 is operable to supply gas to vessel 522 at a pressure and a flow rate sufficient, for the alloy used, to achieve alloy 15 discharge from vessel 522 as detailed herein with reference to filling die cavity 12 of apparatus 10 and/or to achieving sprue metal microstructure for a casting produced with apparatus 10.

Figure 9 shows an arrangement which is similar to that of Figure 1. 20 Corresponding parts have the same reference numeral, plus 600.

In apparatus 610 of Figure 9, the transfer vessel 622 is immersed in the alloy 618 contained in pot 617 of furnace 616. The arrangement for the supply of a measured quantity of alloy 618a from the housing 630 of supply means 620 otherwise is similar, and the supply is achieved with the supply of air pressure 25 to housing 630, from source 643 via connector 642. The inlet port for housing 630 and its valve, corresponding to port 34 and valve 36 of apparatus 10 of Figure 1, are not shown, but they may be similar to the arrangement of Figure 1.

Conduit 664, by which alloy is forced from vessel 622, is formed in a thickened wall portion of vessel 622, and opens through cover 632 of furnace 30 616. A nozzle 97 provides a vertical continuation of conduit 664 above furnace 616. Nozzle 97 communicates via sprue region 98, and runners 665 with each of two die cavities 612 defined between fixed die part 614 and movable die part 614a, with the die parts 614, 614a clamped together by platens 98, 99 mounted on tie bolts 100.

Alloy is displaced from housing 630 to vessel 622 with valve 654 open. The valve 654 then is closed and alloy in vessel 622 is forced from vessel 622, via outlet 662 and conduit 664, to fill each die cavity 612. For this, high pressure gas from source 673 is supplied to vessel 622, via pressurising port 5 668, on opening valve 670a of line 670.

In the apparatus 610 of Figure 9, furnace 616 maintains substantial control over the temperature of alloy in pot 617, housing 630 and vessel 622. However, if required, the head of vessel 622 above cover 632 and the nozzle 97 can be heated by induction, or other suitable means.

10 In each form shown in the drawings, the transfer vessel has a lower part and an upper part, and these may be separable parts or functionally distinct parts which are not separable. As indicated in relation to the arrangement of Figures 1 and 2, transfer vessel 22 is mounted on support means (not shown). This applies to each of the other forms illustrated. However, in each case in 15 which the lower and upper parts are separable, the arrangement most preferably is such that the lower part can be replaced by another of different capacity, with corresponding adjustment or replacement of the conduit by which each vessel is connectable to a die tool. Each transfer vessel can be adapted for use in the production of castings of a range of sizes, by adjustment of the measured quantity of alloy supplied. However, in each case, this range can be 20 extended, for the production of smaller or larger castings, by suitable replacement of its lower portion. The support means preferably is adjustable to accommodate larger or smaller lower portions.

With use of the apparatus 10 of Figures 1 and 2, or with such apparatus 25 modified in accordance with any one of Figures 3, 4, 5, or with the apparatus of each of Figures 6, 7, 8 or 9, operation is controlled in a manner appropriate for a given casting, or a plurality of given castings to be produced in each casting cycle. Thus, with reference to apparatus 10 of Figures 1 and 2, by way of example, the volume and pressure of low pressure gas supplied to housing 30, 30 via port 40, is controlled to ensure the quantity of alloy caused to flow into transfer vessel 22 is sufficient for producing the given casting or castings in a next casting cycle. That quantity is additional to a further quantity of alloy initially provided in the transfer vessel 22 and retained after each casting cycle.

Also with reference to Figures 1 and 2, by way of example, the high pressure gas charged to the transfer vessel 22 is controlled to ensure that the required quantity of alloy in that vessel, which is caused to flow into the die cavity 12, is sufficient to fill the die cavity. The high pressure gas also is controlled so as to be supplied to the transfer vessel 22 at a pressure and a flow rate sufficient to achieve a rapid flow rate of the alloy into the die cavity 12 and, hence, rapid filling of that cavity.

The flow rate of alloy into the die cavity 12 will vary not only with the control over supply of high pressure gas to the transfer vessel, but also with the cross-section of the flow path of the alloy from the transfer vessel 22 to the die cavity 12. That cross-section is represented at various parts of the flow path by the area of the outlet port 62, and the cross-sectional areas of the bore of conduit 64, the main runner 65, the tangential runners 65a and 65b, and the opening from runners 65a, 65b to the die cavity 22 (represented in Figure 1 by gate 66). The required rapid flow rate into the die cavity 12 is an important stage of the overall flow-path, while the required flow rate into the die cavity 12 also depends on the alloy in question. For a given apparatus arrangement, the pressure and flow rate of high pressure gas supplied to the transfer vessel is to achieve the required flow rate of alloy into cavity 12.

For the present invention, excellent casting conditions are found to be achieved by an alloy flow velocity, over a short flow path length up to, or just beyond, the opening into the die cavity which is high relative to the flow velocities at the gate in conventional pressure die casting practice. Also, it is preferred that the high flow velocity over that short flow path length is less than the flow velocity in the runner system preceding that short length. This flow velocity relationship is the converse of that used in conventional practice, as such practice uses a gate cross-sectional area which is less than the runner cross-sectional area and thus gives rise to a higher flow velocity at the gate than in the runner system preceding the gate. Again, the pressure and flow rate of gas to the transfer vessel 12 most preferably provide this.

In relation to Figure 1, there is designated as being a gate 66 by which alloy enters the die cavity 12 from runners 65a and 65b. Such gate is of elongate form and extends between the remote ends of each of runners 65a and 65b, across a delta region at the junction between runners 65a and 65b

and main runner 65. This is a conventional arrangement, for which the term "gate" is appropriate in indicating a constricted opening to cavity 12 which provides an increase in flow rate compared with the flow rate in runners 65a and 65b. However, while that conventional arrangement can be used with 5 apparatus according to the present invention, such as apparatus 10 of Figures 1 and 2, it is preferred that the converse of that flow rate relationship be used. That is, it is preferred that the flow path over a short flow path length up to, or just beyond, the opening into the die cavity increases in cross-sectional area relative to the preceding runner cross-sectional area (most preferably the 10 immediately preceding runner cross-sectional area) to provide flow velocities in the short length which, while higher than conventional gate flow velocities, is less than the runner flow velocity. The term "gate" is not appropriate for such short flow path length since, rather than providing a constriction, it provides a controlled expansion region or port (herein designated as a "CEP") for the alloy 15 being cast.

The flow velocities through the CEP, generated by the pressure and flow rate of gas supplied to the transfer vessel, may exceed the flow velocity through the runner to an extent resulting from the difference in cross-sectional areas of the inlet of the CEP and its runner. For a magnesium alloy, the flow velocity 20 through the inlet to the CEP preferably exceeds about 60 m/s, although it may be as high as from 140 m/s to 165 m/s. While that cross-sectional area ratio generally is applicable to other light alloys, the flow velocities can be lower for those alloys than for magnesium alloys, even though they generally are higher than used in conventional pressure casting. For aluminium alloys, for example, 25 the flow rates through the CEP inlet may exceed about 40 m/s, and preferably exceeds 50 m/s, such as from 80 m/s to 120 m/s, preferably from 80 to 110 m/s. For other alloys, the CEP inlet flow velocity may be similar to that for aluminium alloys, although the range can vary with the unique characteristics of individual alloys. The increasing cross-sectional area of a CEP is such that, for each 30 alloy, the flow velocity at the outlet end of the CEP is from 50 to 80%, such as from 65 to 75%, of the flow velocity at the CEP inlet end. However, for each light alloy, but particularly so for magnesium and aluminium alloys, it is preferred that substantially all of the alloy, at least during its flow in the die tool is in a viscous or semi-solid state. In such state, the alloy may have a solids

content in excess of 35 volume %, such as in the range of from about 40 volume % to about 55 volume %. Such levels of solids content is able to be achieved, despite the alloy in the transfer vessel being in a fully molten condition, due to solidification being initiated under dynamic conditions, i.e. with  
5 gross and homogeneous concentration and thermal gradients.

As an alternative, or in addition, to such alloy flow velocities, the required parameters of pressure and flow rate of gas supplied to the transfer vessel may be determined with reference to the microstructure achieved in sprue metal which separates with a casting produced in the die cavity. The required  
10 microstructure of the sprue metal is characterised by fine banding normal to the metal flow direction. The banding may have a spacing (or wavelength) between centres of successive bands which is of the order of about 40 µm for magnesium alloys and about 200 µm for aluminium and other alloys, and results from segregation of elements of the alloy. This microstructure is achieved with  
15 use of a suitable CEP. However, it can be achieved with other arrangements such as in an outlet end portion of a runner which opens to its die cavity other than through a CEP. The pressure and flow rate for gas supplied into the transfer vessel largely is exemplified with reference to the apparatus 10 of Figure 1. However, it is to be understood that these parameters apply to other  
20 apparatus according to the present invention, such as apparatus 410 of Figure 7, apparatus 510 of Figure 8, and apparatus 610 of Figure 9.

The level of pressure used in relation to the supply means of apparatus 10 of Figure 1, as well as apparatus 410 of Figure 7, apparatus 510 of Figure 8 and apparatus 610 of Figure 9, can be low relative to the pressure of gas supplied in each case to the transfer vessel. Whether based on use of gas pressure as in apparatus 10 and 610, or a piston as in each of apparatus 410 and 510, the pressure used for the supply means need be no greater than is necessary to achieve efficient supply of a measured quantity of alloy to the respective transfer vessel. In the case of respective apparatus 10 and 610, the  
25 volume and pressure of the gas supplied to the supply means, and the time interval for which it is used, is such as to supply such measured quantity of alloy, whereas with the respective apparatus 410 and 510, the stroke of the respective piston for the supply means is set to provide that quantity.

As detailed in the general description preceding reference to the drawings, the apparatus of the invention has a number of practical benefits and is amenable to modification. Some of the benefits and modifications will be apparent from the description with reference to the drawings. Thus, it will be  
5 readily apparent that, in each of apparatus 10, 410, 510 and 610, there can be at least one further transfer vessel, to enable concurrent or sequential casting in respective die tools.

In the preceding description of the drawings, the reference is to arrangements utilising an external source of pressurising gas by which alloy is  
10 caused to flow from the transfer vessel to a die cavity. However, as previously indicated, the flow of alloy may be caused by the supply of an oxygen-containing gas and a suitable fuel to the transfer vessel, for combustion of the fuel and generation of pressurising combustion gases. Modification of the arrangements for such supply and combustion will be readily understood by  
15 those skilled in the art.

Finally, it is to be understood that various alterations, modifications and/or additions may be introduced into the constructions and arrangements of parts previously described without departing from the spirit or ambit of the invention.

## CLAIMS:

1. Apparatus for use in for high pressure casting of alloys, wherein the apparatus includes a molten alloy transfer vessel which has capacity for holding a measured volume of alloy required for transfer to a die tool and sufficient for a single casting cycle to produce at least one casting; wherein the transfer vessel has a valve controlled charging port at an upper region of the transfer vessel by which the measured volume of alloy is able to be charged into the vessel, and an outlet port at or adjacent to a base of the vessel, through which the alloy is able to be discharged for flow to a die tool; and wherein the transfer vessel has a gas supply port at the upper region thereof for the supply of gas above the surface of a measured volume of alloy received therein whereby the vessel is able to be pressurised for discharging alloy therein through the outlet port for flow to the die tool.
- 15 2. The apparatus of claim 1, further including a source of pressurised gas from which a supply of the gas is able to be charged to the transfer vessel via the gas supply port whereby, with the supply of pressurised gas to the transfer vessel, the measured quantity of alloy is caused to be discharged from the vessel at a flow rate in a required flow rate range, during a single casting cycle.
3. The apparatus of claim 1, wherein the transfer vessel is adapted to function as a combustion chamber, with the gas supply port enabling an oxygen-containing gas to be charged to the transfer vessel from gas supply means; and wherein the apparatus further includes means for charging a suitable fuel to the transfer vessel to form a combustible oxygen/fuel mixture with the oxygen-containing gas, and the transfer vessel is able to be pressurised by combustion of that mixture, whereby the measured quantity of alloy is able to be caused to discharge from the transfer vessel, at a flow rate in a required flow rate range, during a single casting cycle by the action of hot combustion gases.

4. The apparatus of claim 3, wherein the apparatus includes means for supplying oxygen-containing gas and fuel, in a metered ratio, and means for igniting the oxygen/fuel mixture.
- 5 5. The apparatus of claim 3, wherein the means for charging the fluid is operable to inject the fuel after the oxygen-containing gas has been charged to the pressure vessel and the gas supply port has been closed, to thereby form an oxygen/fuel mixture which is spontaneously ignitable on coming into the proximity of the molten metal.
- 10 6. The apparatus of claim 3, further including an ante-chamber in which the oxygen/fuel mixture initially is held and which is closed prior to opening the gas-supply port to admit the mixture to the transfer vessel for spontaneous combustion on coming into the proximity of the molten metal.
- 15 7. The apparatus of any one of claims 1 to 6, wherein the outlet port is in communication with a die cavity defined by the die tool via a runner, and the apparatus is operable to discharge alloy through the outlet port, for flow along the runner to the die cavity, whereby a relatively high alloy flow velocity is achieved in the runner.
- 20 8. The apparatus according to claim 7, wherein an alloy flow path, between the outlet port and the die cavity, includes the runner and further includes, over a short part of the length of the flow path, a controlled expansion port (herein a "CEP") which increases in cross-sectional area from an inlet end to an outlet end of the CEP whereby the alloy flow velocity decreases from the inlet end to the outlet end of the CEP.
- 25 9. The apparatus according to claim 8, wherein the apparatus is operable to achieve an alloy flow velocity at the inlet end of the CEP and an alloy flow velocity at the outlet end of the CEP whereby the molten alloy discharged from the outlet port is caused to undergo a change from a molten state to a semi-solid state in its flow through the CEP.

10. The apparatus according to claim 9, wherein the flow path is such that the alloy is maintained in the semi-solid state substantially throughout its flow into the die cavity.

5 11. The apparatus of any one of claims 1 to 10, wherein the transfer vessel defines a sleeve which is closed at an upper end by a plunger, with the plunger of the transfer vessel being movable between an upper position in which it clears an opening in the wall of its sleeve defining the charging port and a lower position in which the plunger functions as a valve closing the charging port.

10 12. The apparatus of claim 11, wherein the plunger of the transfer vessel has an axial bore therethrough which defines the gas supply port by which, with the charging port closed by the plunger, pressurised gas is able to be supplied to the transfer vessel for discharging alloy from the vessel through the outlet port.

15 13. The apparatus of any one of claims 1 to 12, wherein flow control means is provided at the pressurising port for preventing pressurising gas from issuing as a jet which impinges narrowly on the upper surface of molten alloy in the transfer vessel.

20 14. The apparatus of claim 13, wherein the flow control means is a helical baffle which guides the gas in a helical flow path towards the alloy.

15. The apparatus of claim 13, wherein the flow control means is a conical member which diffuses the gas flow into a conical stream.

25 16. The apparatus of any one of claims 1 to 12, wherein the pressurising port opens laterally such that a gas jet issuing therefrom does not impinge directly on the upper surface of alloy in the transfer vessel.

30 17. A pressure casing machine, for use in pressure casting of alloys, wherein the machine includes the apparatus of any one of claims 1 to 16, and means for supplying molten alloy to the transfer vessel of said apparatus

18. The pressure casting machine of claim 17, wherein the supply means includes a pot or furnace in which a supply of the alloy for successive casting operations is kept molten at a suitable temperature for casting.
- 5 19. The pressure casting machine of claim 18, wherein the supply means is operable to pass a measured quantity of alloy, from the supply in the pot or furnace, into the transfer vessel.
- 10 20. The pressure casting machine of claim 19, wherein the supply means is associated with the pot or furnace and is at least partly submerged in the supply of alloy in the pot or furnace.
- 15 21. The pressure casting machine of any one of claims 18 to 20, wherein the supply means comprises a plunger which is vertically movable in a cylindrical housing mounted in the pot or furnace, with the plunger movable in the housing between a raised position in which it clears an opening in the cylindrical wall of the housing for drawing alloy into the housing, and a depressed position in which it displaces the alloy from the housing into the transfer vessel.
- 20 22. The pressure casting machine of any one of claims 18 to 20, wherein the supply means includes a housing which is mounted in the pot or furnace and is closed at its upper end, and wherein the housing is provided with an inlet port by which a pressurised gas is able to be supplied to displace alloy from the supply means into the transfer vessel.
- 25 23. The pressure casting machine of any one of claims 18 to 22, wherein the transfer vessel defines a sleeve which is closed at an upper end by a plunger, with the plunger of the transfer vessel being movable between an upper position in which it clears an opening in the wall of its sleeve defining the charging port and a lower position in which the plunger functions as a valve closing the charging port.
- 30 24. The pressure casting machine of claim 23, wherein the plunger of the transfer vessel has an axial bore therethrough which defines the gas supply port

by which, with the charging port closed by the plunger, pressurised gas is able to be supplied to the transfer vessel for discharging alloy from the vessel through the outlet port.

5 25. The pressure casting machine of any one of claims 18 to 22, wherein the transfer vessel comprises a housing which, apart from the charging, outlet and gas supply ports, is sealed.

10 26. The pressure casting machine of any one of claims 18 to 25, wherein the transfer vessel is mounted in the pot or furnace.

27. The pressure casting machine of any one of claims 17 to 26, including conduit means providing communication between the supply means and the transfer vessel.

15 28. The pressure casting machine of claim 27, wherein the conduit means is continuous between an outlet port of the supply means housing and the charging port of the transfer vessel.

20 29. The pressure casting machine of claim 28, wherein the conduit means has a first portion which extends upwardly in the wall of the supply means housing and which, at its lower end, is in communication with the interior of the housing, and a second portion which extends laterally from the upper end of the first portion to the charging port of the transfer vessel.

25 30. The pressure casting machine of claim 29, wherein a control valve for the charging port, for enabling and preventing communication between the supply means and the transfer vessel is associated with the second portion of the conduit means.

30 31. The pressure casting machine of claim 30, wherein the control valve has a valve head mounted on a valve stem for movement across the second portion of the conduit means, and wherein a valve seat against which the valve head is

sealable is defined within the conduit means, with the valve stem extending from the valve head away from the first portion.

32. The pressure casting machine of claim 30, wherein the control valve has  
5 a valve head mounted on a valve stem for movement longitudinally with respect to the second portion, and wherein a valve seat against which the valve head is sealable is defined by the second portion of the conduit means, with the valve stem extending from the valve head, within the second portion, away from the charging port.
- 10 33. The pressure casting machine of claim 31 or claim 32, wherein the valve stem projects exteriorly of the conduit means to an actuator operable to close and open the valve.
- 15 34. The pressure casting machine of any one of claims 31 to 33, wherein the second portion of the conduit means is inclined downwardly towards the charging port to enable drainage of alloy therefrom into the transfer vessel, to thereby minimise risk of alloy at the valve seat impeding closing of the valve.
- 20 35. The pressure casting machine of claim 30, wherein the conduit means terminates short of the charging port, with an end of the second portion remote from the first portion terminating above an open-topped receptacle on the exterior of the transfer vessel, adjacent to the charging port, whereby the conduit means is able to discharge alloy into the receptacle for flow into the  
25 transfer vessel, via the charging port.
36. The pressure casting machine of any one of claims 31 to 34, wherein a vent is provided at the valve so that blowing of gas into the supply means is prevented in the event that closing of the valve is prevented by a blockage or  
30 malfunctioning of the valve.
37. The pressure casting machine of claim 36, wherein the vent is provided by a further conduit portion which extends upwardly from the second portion adjacent to the vessel, to provide a path of low resistance to the passage of the

gas therethrough in preference to flow through the first conduit portion against a pressure head of alloy in the supply means.

38. The pressure casting machine of claim 37, wherein the further conduit  
5 portion has a relief valve therein which opens in response to gas pressure, but  
not in response to a lower pressure at which alloy is caused to flow from the  
supply means to the transfer vessel.

17

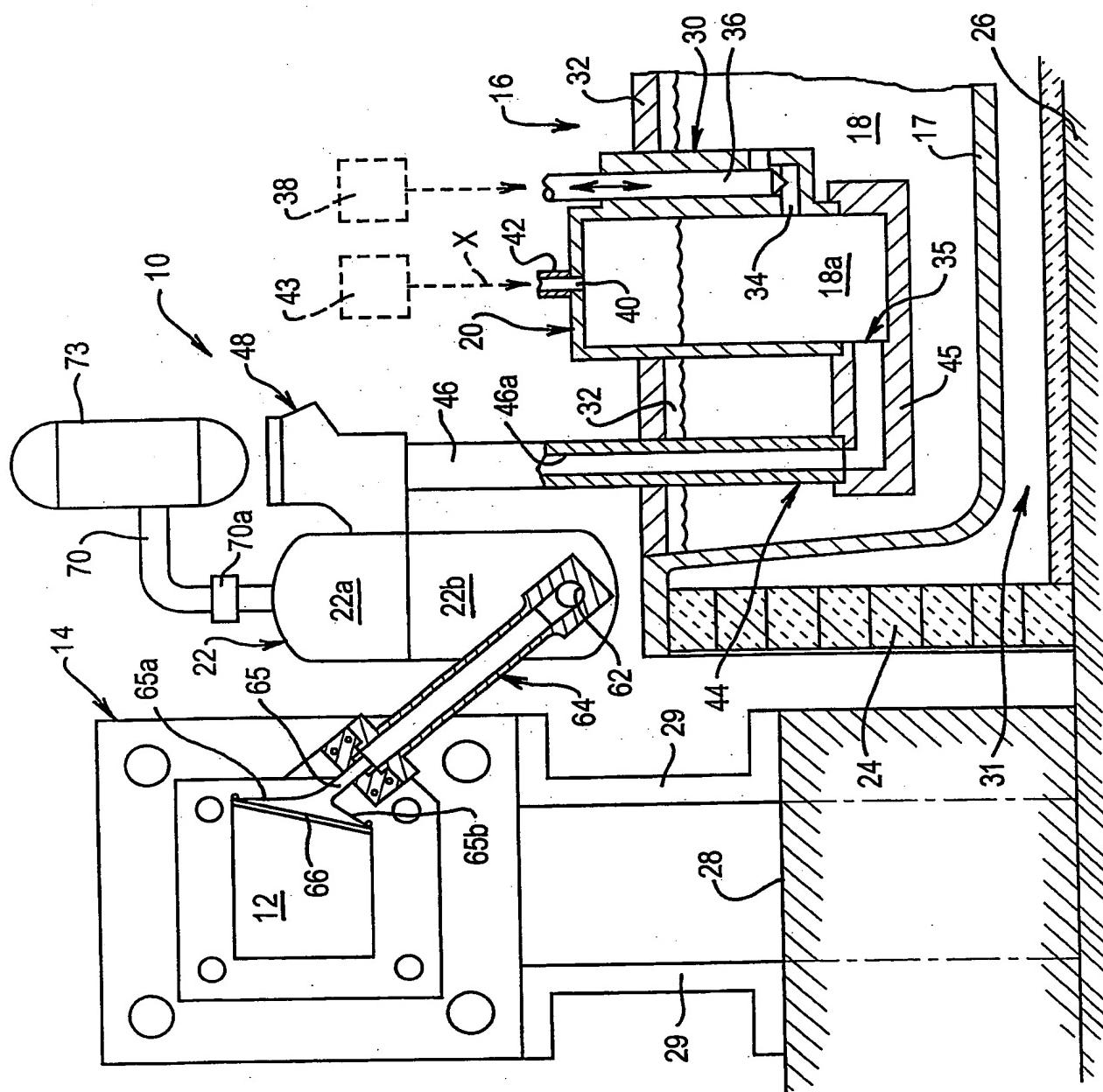
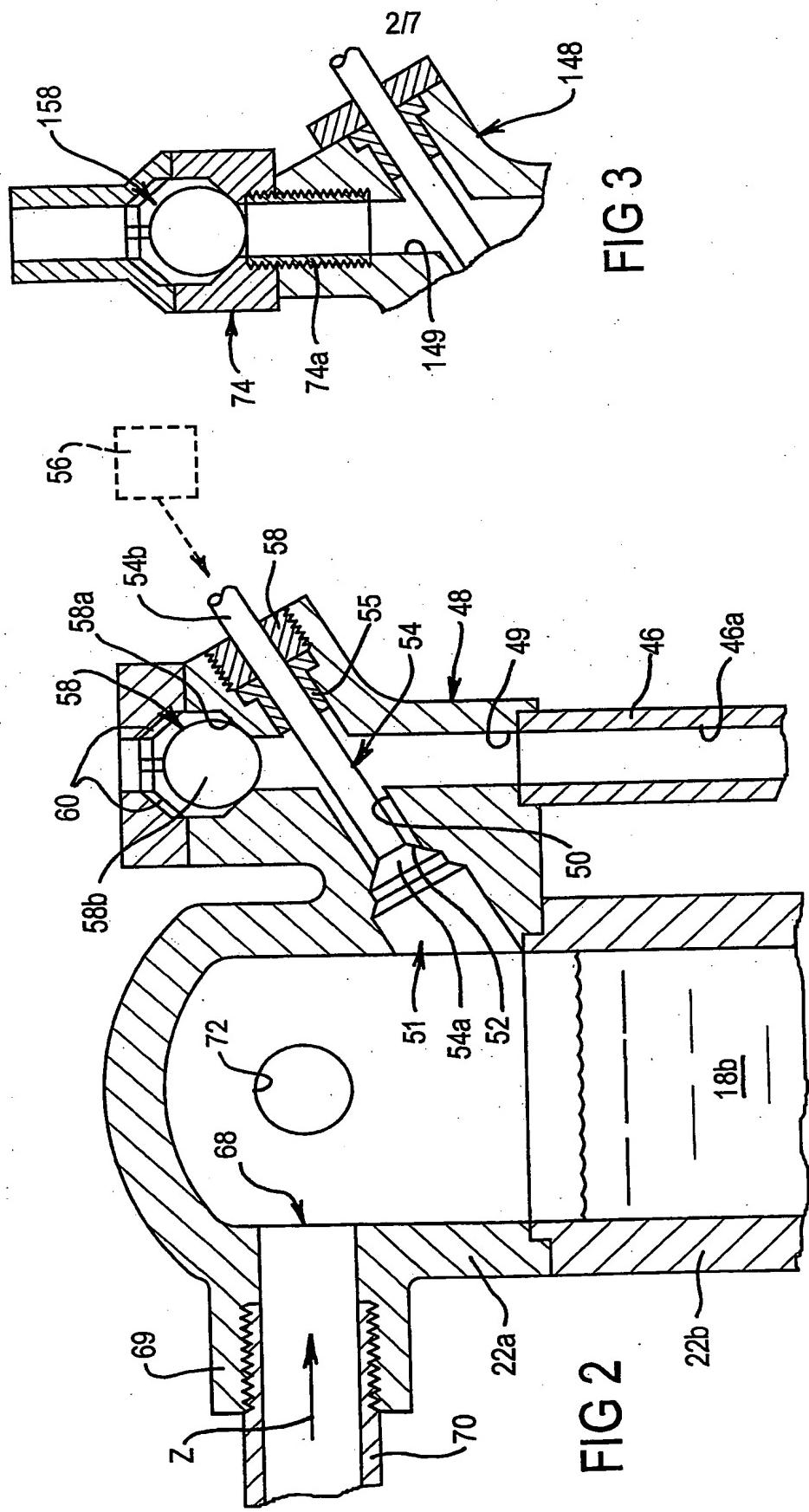


FIG 1



3/7

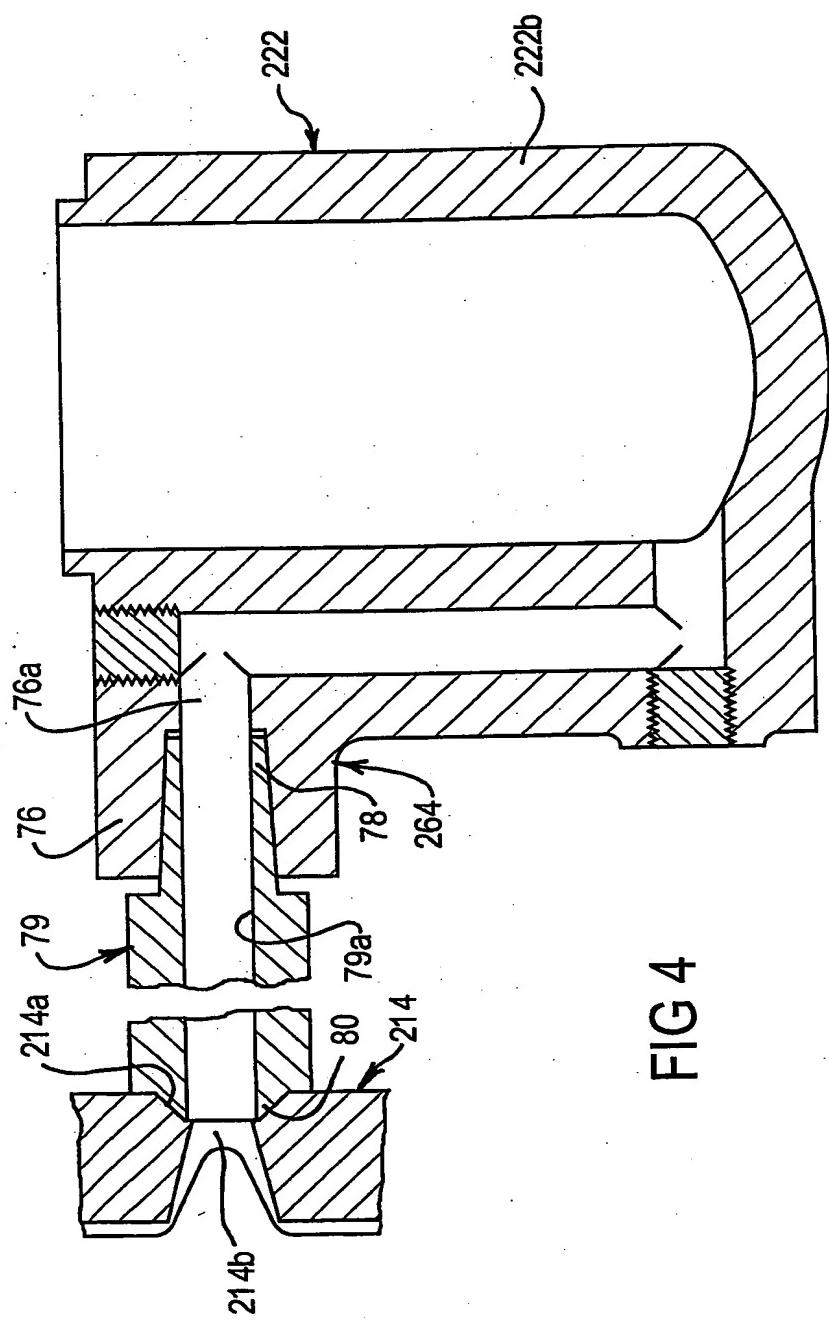


FIG 4

4/7

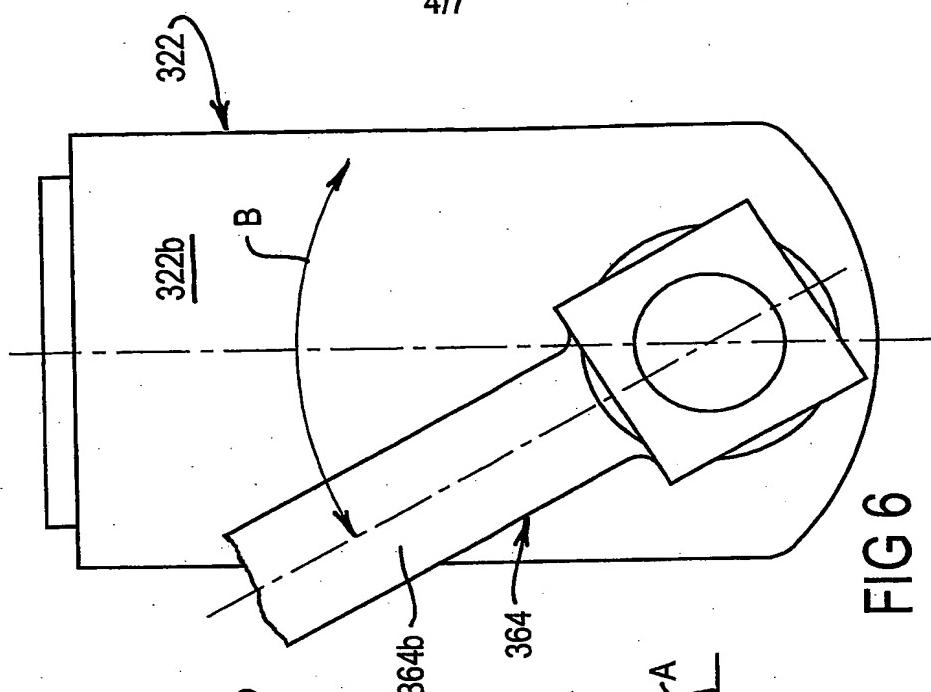


FIG 6

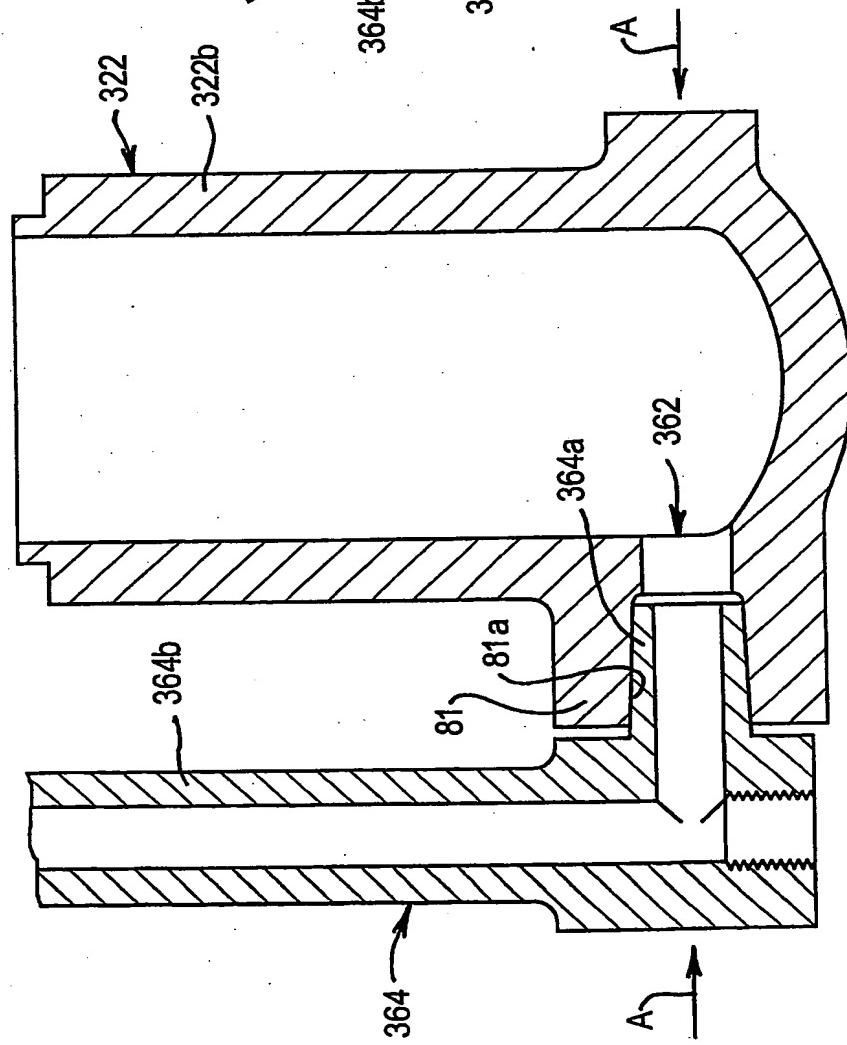
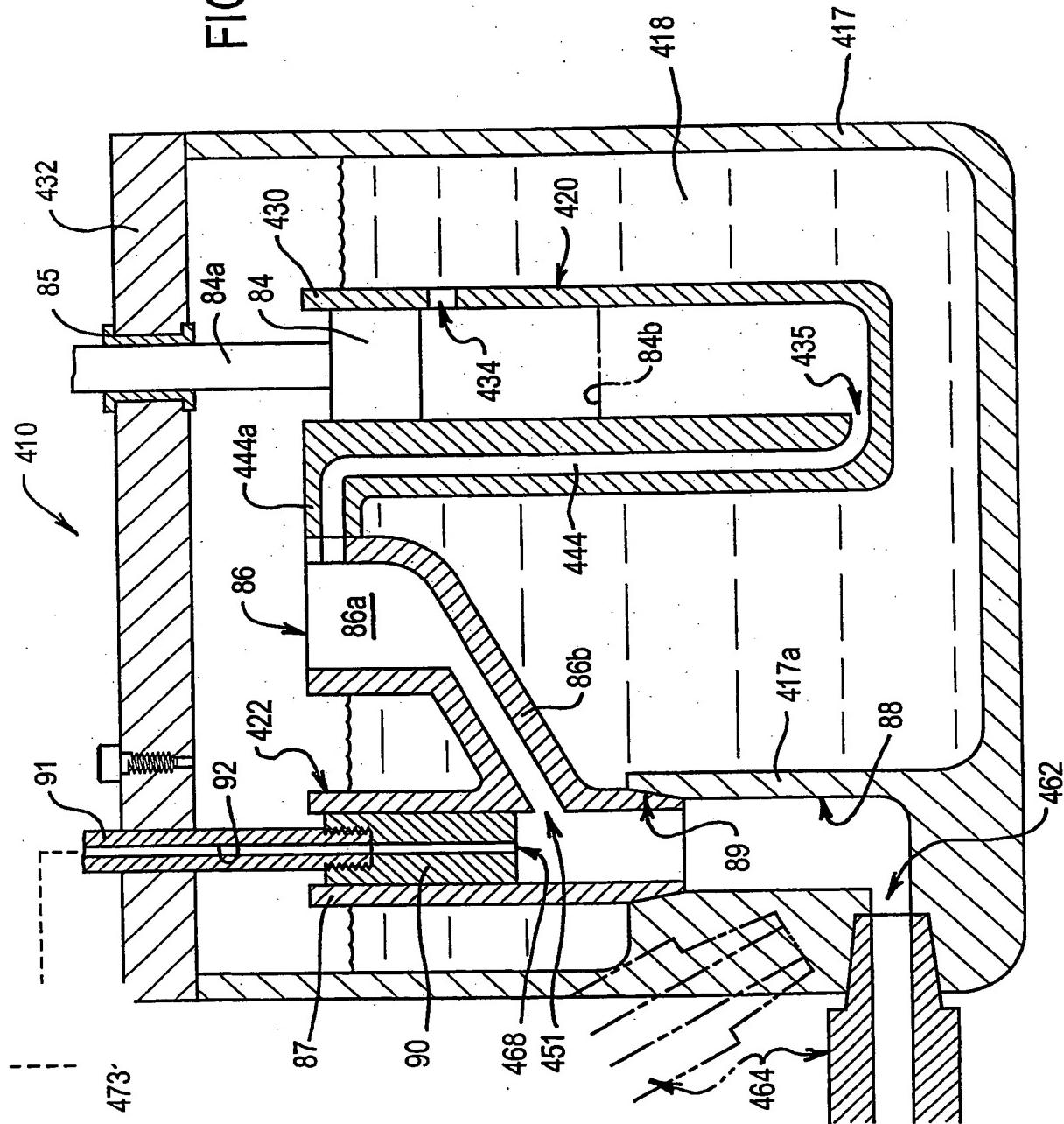


FIG 5

5/7

FIG 7



6/7

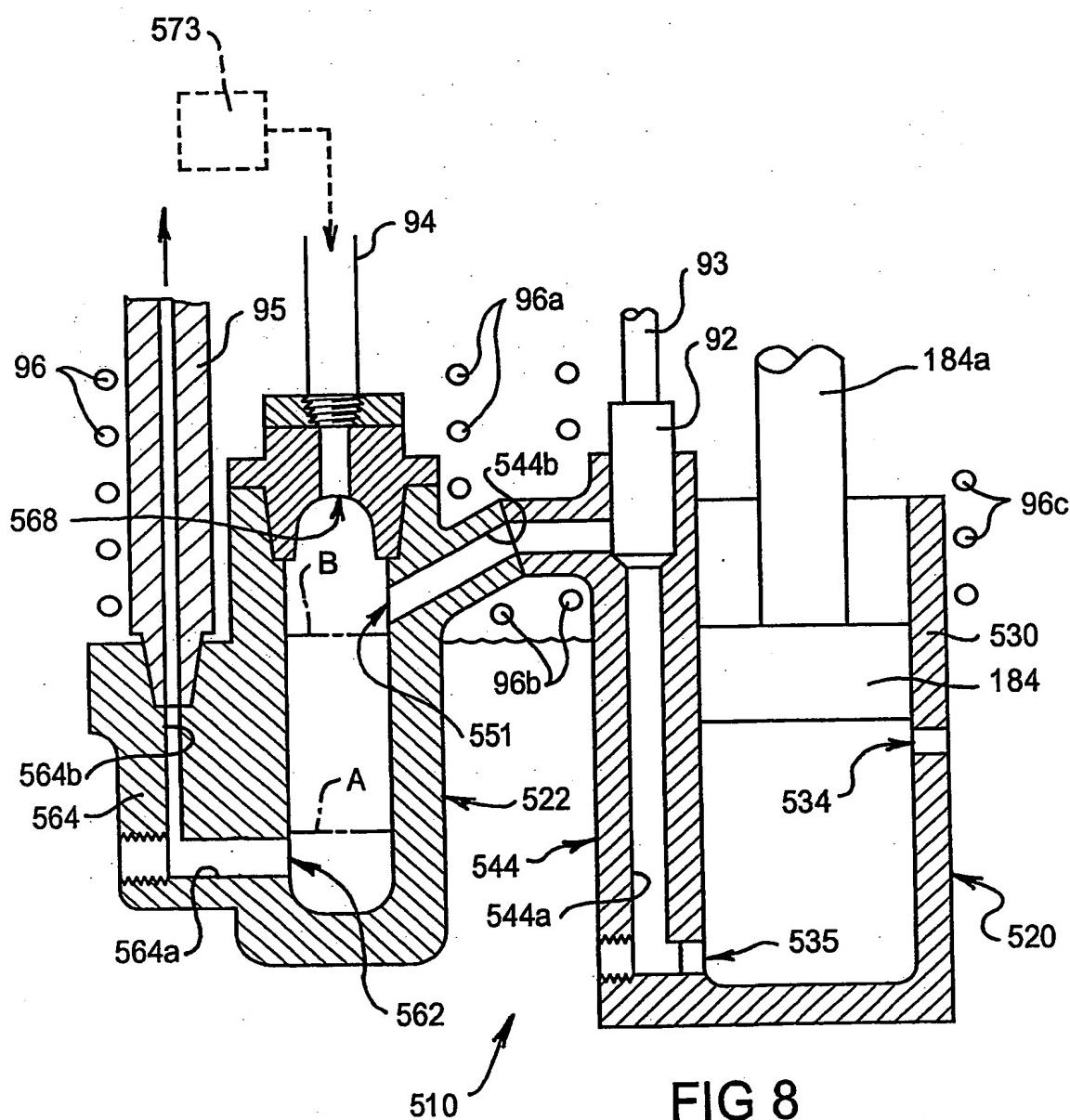


FIG 8

7/7

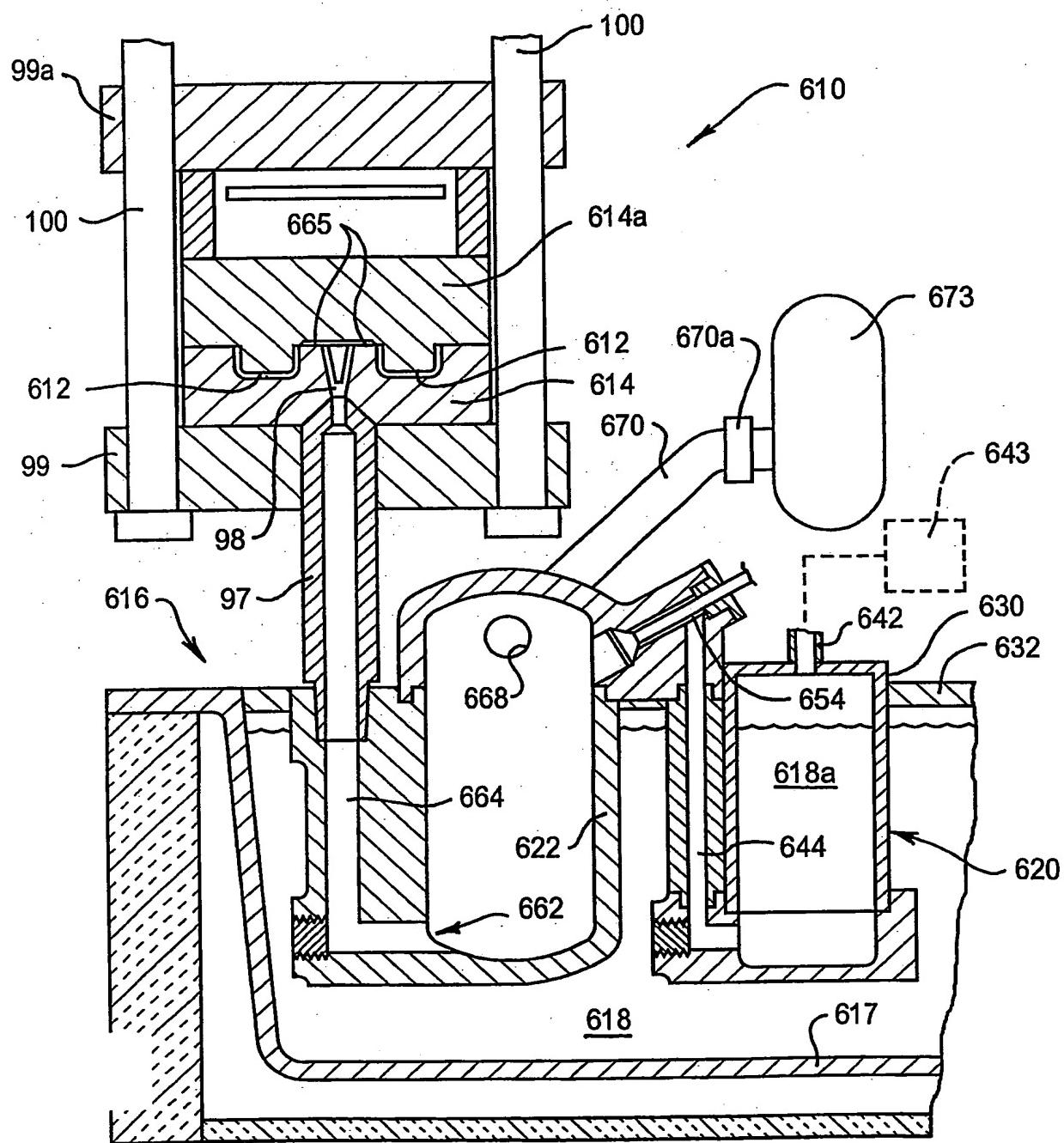


FIG 9

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/AU02/01141

## A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. <sup>7</sup>: B22D 17/30

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC<sup>7</sup> as above

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practicable, search terms used)  
Derwent WPAT: IPC<sup>7</sup> as above and vessel+ or chamber+ or volum+ or gas or gases

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Derwent Abstract Accession No. 2001-435974/47, Class A32, M22, JP 2001-121250 A (Toshiba Machine Co Ltd) 5 August 2001 Abstract	
A	Derwent Abstract Accession No. 09838 K/05, Class P53, DE 3050183 (Norsk Hydro Magnesium) 27 January 1983 Abstract	
A	Derwent Abstract Accession No. 75866 D/42, Class M22, P53, DE 3012047 (Norsk Hydro A/S) 8 October 1981 Abstract	

Further documents are listed in the continuation of Box C  See patent family annex

"A"	Special categories of cited documents: Document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the International filing date but later than the priority date claimed		

Date of the actual completion of the International search  
20 September 2002Date of mailing of the International search report  
27 SEP 2002Name and mailing address of the ISA/AU  
AUSTRALIAN PATENT OFFICE  
PO BOX 200, WODEN ACT 2606, AUSTRALIA  
E-mail address: pct@ipaaustralia.gov.au  
Facsimile No. (02) 6285 3929

Authorized officer

DAVID K. BELL  
Telephone No : (02) 6283 2309

**This Page is Inserted by IFW Indexing and Scanning  
Operations and is not part of the Official Record**

**BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- BLACK BORDERS**
- IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- FADING TEXT OR DRAWING**
- BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- SKEWED/SLANTED IMAGES**
- COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- GRAY SCALE DOCUMENTS**
- LINES OR MARKS ON ORIGINAL DOCUMENT**
- REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- OTHER:** \_\_\_\_\_

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.**